4-05.1 APPROACHES AND DRIVEWAYS. The location and design of approaches and driveways affect the safety and traffic handling capacity of the highway. Therefore, the location and design of each such feature receives careful consideration. The number of access points is held to a minimum with due consideration to the type of facility being designed, convenience to the highway user, and convenience of access to adjacent property. Each driveway and approach should be designed with appropriate width and radius which will permit entry of controlling design vehicle without encroachment on opposing traffic lanes.

4-05.1 (1) NUMBER. Direct access is not allowed to the through lanes on freeways designed with full control of access. The number of access points is held to a practicable minimum on facilities designed with controlled access right of way. On other facilities only the minimum number of access points necessary to provide convenient access to adjacent properties is allowed.

4-05.1 (2) DESIGN STANDARDS. Driveways are designed in accordance with the details on the standard plans. The grade controls given on the standard plans are adhered to if at all practicable. The department's Driveway Permit Manual defines driveway types and includes basic design criteria for each. The minimum desirable radii, surface type, and thickness for driveways are tabulated in Table 4-05.1.

TABLE 4-05.1
DRIVEWAY MINIMUM STANDARDS

TYPE APPROACH AND RECOMMENDED USAGE	MINIMUM RADIUS	MINIMUM SURFACE
Driveway Type I Field or Private Entrance	10 ft. [3.0 m]	4 in. [100 mm] - Aggregate with 2 in. [50 mm] A.C. or Bit. Pav't to radius point
Driveway Type II City/County Road	30 - 50 ft. [9.0 - 15.0 m]*	4 in. [100 mm] - Aggregate with 2 in. [50 mm] A.C. or Bit. Pav't to right of way line
Driveway Type III Commercial Entrance	10 - 40 ft. [3.0 - 12.0 m]	4 in. [100 mm] - Aggregate with 2 in. [50 mm] A.C. or Bit. Pav't to right of way line
Driveway Type IV Truck Entrance	50 ft. [15.0 m]	6 in. [150 mm] - Aggregate with 2 in. [50 mm] A.C. or Bit. Pav't to right of way line
Driveway Type V Volume Product	90-95 ft. [28.0 m]	Est. by Design
Alley	5 - 10 ft. [1.5 - 3.0 m]	4 in. [100 mm] - Aggregate with 2 in. [50 mm] A.C. or Bit. Pav't to right of way line

* Without signals

4-05.1 (3) COMMERCIAL DRIVEWAYS. Commercial driveways are designed in accordance with the details on the standard plans. The maximum width of commercial driveways measured at the radius point is 60 ft. [18 m]. The width specified on the plans is the width measured normal to the centerline of the entrance. A 4 in. [100 mm] barrier concrete or asphalt curb or concrete curb and gutter is specified for the delineation of commercial driveways and along the right of way line as necessary to restrict use of right of way area as indicated on the standard plans. Driveways are located relative to property line and to other driveways in accordance with the standard plans whenever possible.

4-05.1 **(4) MAILBOX TURNOUTS AND SUPPORTS.** Mailbox turnouts apply to resurfacing projects. Mailbox turnouts may be provided on resurfacing projects which include some earthwork, such as shaping shoulders. Consideration should be given to inclusion of this item where the finished shoulders are not of sufficient width to allow a vehicle to get off the traveled way.

Shoulder widths of less than 8 ft. [2.4 m] require special mailbox turnouts in accordance with the standard plans. When shoulders 8 ft. [2.4 m] and wider are provided, special mailbox turnouts will not be necessary.

When stabilization is not provided on shoulders, provide 4 in. [100 mm] of Type 1 or 2 aggregate with 2 in. [50 mm] plant mix bituminous pavement surfacing for mailbox turnouts.

Use pipe only when required by restrictive right of way or extreme drainage condition.

AASHTO has prepared a guide for erecting mailboxes on highways which was approved as an informational guide by the executive committee of AASHTO on May 24, 1984. The guide states that a nominal 4" x 4" [100 x 100 mm] square or 4 $^{1}/_{2}$" [115 mm] diameter wood posts or 1 $^{1}/_{2}$" to 2 " [38 to 50 mm] standard steel or aluminum pipe posts, embedded no more than 24 in. [600 mm] into the ground, are the maximum strength supports which should be considered for mailboxes. Figure 4-05.5 shows mailbox assembly standards.

During the design stage of the project, any mailbox support which is noted to be in gross violation of the approved mailbox supports (as shown in Figure 4-05.5) should be noted by location. Notice of these mailboxes should be sent to the local postmaster requesting their assistance in requiring the mail patron to change the mailbox support to comply with national standards and reduce the potential safety hazard. Figures 4-05.3 and 4-05.4 are examples of the letter to be sent to the local postmaster. The design file should document the fact that such mailboxes were checked and further document the action taken through the local postmaster. The District Operations Engineer should be furnished copies of necessary correspondence for use after award of the contract.

4-05.2 **MEDIAN OPENINGS.** Median openings are considered only at state routes, county roads, and major streets. Details for median openings are shown in the Standard Plan 203.50. Maintenance and emergency median openings are constructed by district maintenance forces and are not considered in the design plans.

If a median opening is to be constructed of portland cement concrete, the plans should show the joint layout. To avoid sympathy cracks in the traveled way, it is desirable to match median opening joints with the adjacent traveled way joints and avoid specifying a median opening joint which will intersect the adjacent traveled way where no joint exists. It is acceptable for joints in the centerline of the median opening not to match directly. See Subsection 6-03.4 (3) for joint information

4-05.3 **STATE ROUTES AND IMPORTANT ROADS AND STREETS.** Highways are designed to ultimately provide for the safe, convenient and economical transportation of persons and goods. The success of such design is dependent upon proper planning, geometric design, and efficient traffic operations. It is the intent of this subsection to cover general requirements only. Variations required by location and local conditions will usually offer an infinite number of solutions for specially designed grade intersections.

Designs for important side road intersections are based on a volume product. For volume products equal to or greater than 700,000 the design shown on Standard Plan 203.65 is used. For volume product intersections less than 700,000, see Standard Plans 203.62. The volume product is the product of Vm x Vc. Vm is the design ADT on the major approach (one direction volume for divided and both direction volume for 2-way). Vc is the design ADT on the minor approach.

Efficient traffic operation is dependent upon geometric design. It is desirable that the geometric design consider traffic signal control as a design criterion at all intersections where traffic conflicts are present. When this is not done and traffic signal control becomes necessary, the net result is usually that signals must often be poorly located with respect to driver vision, protected left turning movements disregarded, and other such necessary requirements for efficient traffic signal control compromised or forgotten.

Grades are designed in accordance with Subsection 4-04.2.

Schematic details for grade intersections are indicated on the preliminary plan, along with traffic data, including turning movements. The preliminary plan approval will constitute approval of the schematics of the intersections.

4-05.3 (1) CAPACITY. The appropriate capacities for grade intersections without signals are given in Table 4-05.2. The capacities for signalized intersections are as follows: The practical capacity of each lane of a signal controlled approach is 1000 passenger cars per hour of green time per 10 ft. [3.0 m] of traveled way width where conflicts with parking, turning movements, commercial vehicles, and pedestrians are at a minimum, and where no vehicles are required to wait more than one time cycle for right of way. This capacity is reduced one per cent for each one per cent of commercial vehicles and uncontrolled left turning movements, and one half of one per cent for each one per cent of right turning vehicles. The average time spacing for moving vehicles at signalized intersections is 2.1 seconds. The maximum traffic volume that can turn left or right from a 10 ft. [3.0 m] wide auxiliary lane in a 30-second phase with ten percent commercial vehicles present is 450 vph for a 60-second time cycle, 300 vph for a 90-second time cycle, and 225 vph for a 120-second time cycle. A two-lane approach for high volume turns will increase these capacities by about 50 percent. Turning movement phases longer than 30 seconds, except at Tee intersections, are not practical and are not used for design purposes. The foregoing volumes for turning vehicles should be used as a guide only. A more detailed capacity analysis should be made as outlined in the Highway Capacity Manual, to determine the exact needs and requirements for a signalized intersection.

TABLE 4-05.2
TRAFFIC CAPACITIES FOR GRADE INTERSECTIONS WITHOUT SIGNALS
(Two-way Design Hourly Volumes)

2-Lane through Highway	400.00	500.00	600.00
Crossroad	250.00	200.00	100.00
4-Lane through Highway	1000.00	1500.00	2000.00
Crossroad	100.00	50.00	25.00

4-05.3 (2) ISLANDS. Islands are triangular or longitudinal. Triangular islands are generally used on the minor approach to an at-grade intersection; cross-overs for major side roads, state routes and major streets; signalized intersections; and on ramp terminals at the cross-road or streets at interchanges. Islands at ramp termini are used in accordance with Figure 4-06.2. Islands for at-grade intersections shall be in accordance with Standard Plan 203.65. Islands when required at cross-overs shall be in accordance with the standard plans. Where the highway shoulder is carried through the intersection, the island is placed at the edge of the shoulder. The side of a longitudinal island adjacent to through-traffic lanes is offset from the edge of the traveled way by at least 2 ft. [0.6 m]. The island may be offset a greater distance if necessary or desirable to eliminate a particular hazard.

The two primary types of islands used are as follows:

4-05.3 (2) (a) DIVISIONAL ISLANDS. These normally are longitudinal islands used to divide opposing traffic and elsewhere to positively restrict encroachment thereon by vehicles. They are not less than 4 ft. [1.2 m] in width nor less than 12 ft. [3.6 m], preferably 20 ft. [6.0 m], in length. A divisional island nose is offset a minimum of 4 ft. [1.2 m] from the projected edge of the traveled way of the cross road or street. Divisional islands are always constructed with barrier type curbs and basic lighting is provided to the extent necessary to illuminate the ends of such islands. Examples of divisional islands are (a) short bulb-type median islands used to provide protected left turn movements, (b) all islands between opposing traffic streams, and (c) all islands established for the purpose of locating traffic signal poles or lighting poles.

4-05.3 (2) (b) CHANNELIZING ISLANDS. These are islands used to guide and direct same direction traffic streams or diverging traffic streams. Channelizing islands may consist of painted areas, flush sodded areas, or raised islands. The islands are a minimum of 75 ft^2 [7.0 m^2] in area or about 10 ft. [3.0 m] on a side after rounding. Where raised channelizing islands are used, they are always constructed with mountable type curbs. Channelizing islands are not lighted except when lighting is justified by other warrants. Examples of channelizing islands are those established for: (a) guiding parallel or diverging traffic streams, (b) locating small signs, (c) providing pedestrian refuge, and (d) reducing large paved areas at intersections. When questions arise concerning the classification of a particular island which is border line with respect to divisional or channelizing, the particular island should be classed channelizing to preclude the lighting provision. In those cases where it is apparent that traffic signals will be installed within a reasonable time after construction at the intersection or interchange the islands should be designed as divisional and lighted initially. Additional information about islands is given in Chapter 9 of the AASHTO Green Book.

4-05.3 (3) AUXILIARY LANES. These are lanes provided at an intersection to allow turning vehicles to slow and/or store out of the through traffic lanes. It is desirable to provide these lanes at all signalized intersections if practical, even though the turning movement is not separately signal controlled, as the auxiliary lane will tend to reduce accidents, improve intersection capacity, and allow for the most efficient methods of controlling traffic.

4-05.3 (3) (a) LEFT TURN LANES. Left turn lanes are considered at street or road intersections where the number of left-turning vehicles is 100 vph or more during the peak hour. Where the peak hour left-turning traffic exceeds 300 vph, provision for two-lane left turns is considered. Left-turn facilities should be considered on roadways where traffic volumes are high enough or safety considerations are sufficient to warrant them. Exhibit 9-75 of the AASHTO Green Book should be used as a guide to traffic volumes where left-turn facilities should be considered. Traffic volumes shown in Exhibit 9-75 are vehicles per hour (vph). Left turn lane should also be considered at intersections where traffic volumes do not warrant but are required because of poor visibility or accident records indicate a need for safety considerations. Left turn lanes are 10 ft. [3.0 m] minimum in width plus additional width required for striping for flush medians or for curb clearances of barrier curbs for raised medians. Left turn lanes for 30 or 40 mph [50 or 70 km/h] design are developed according to the minimum transitions shown on Figure 4-05.1 (Raised Median) and are constructed using barrier curbs and are lighted to the extent necessary to illuminate the ends. Left turn lanes for 50 or 60 mph [80 or 100 km/h] design are developed according to the minimum transitions shown on Figure 4-05.2 (Flush Median). Left turn lanes developed from continuous medians are constructed with barrier curbs for at least the length of the left turn storage with the barrier end lighted. As a guide, 200 ft. [60 m] is the desirable minimum length for left-turn lanes. An additional length of a constant 10 ft. [3.0 m] minimum width lane is provided and may be required for storage. Data for establishing the storage length is discussed later in this section.

The use of a divisional island at an intersection to separate the left turning traffic from same direction through traffic may be desirable, particularly where opposing traffic is separated by a wide median. This island will make a left turn from an auxiliary left turn lane mandatory and requires lane control signing.

4-05.3 (3) (b) RIGHT TURN LANES. Warrants for right turn lanes are the same as those indicated above for left turn lanes. At signal controlled intersections, these lanes are separated, where practical, from same direction through traffic by a channelizing island to make the right turn mandatory.

An auxiliary right turn lane at signal controlled intersections is provided primarily for storage of right turning vehicles and not for deceleration purposes. To prevent through vehicles from being falsely led into the auxiliary right turn lane, an abrupt taper is used at the beginning of the lane. At locations where it is either impractical or not warranted to provide an auxiliary right turn lane, a channelizing island will reduce right turning maneuver conflicts with through traffic. This movement may be made a "yielding" maneuver. However, a few straight through vehicles stopped for a red indication in the right lane will block the right turn and conversely, a few right turning vehicles stopped while waiting for a gap in the cross street traffic will block the right lane for through vehicle storage.

4-05.3 (3) (c) EXACT LENGTH OF AUXILIARY LANES. The exact length of a full width auxiliary lane necessary for storage of vehicles desiring to turn left or right at signal controlled intersections is determined on the basis of the maximum possible total time cycle, peak hour traffic volume, and average storage length required per vehicle.

The exact length necessary is calculated by multiplying the average length required per vehicle (both trucks and cars) times the number of vehicles arriving per time cycle in the peak hour and is determined by the formula:

$$L = \frac{(\%PC \times 25) + (\%TK \times 40)}{100} \times \frac{(vph) \times (cl)}{3600} \times 0.3048 \text{ (USE 0.3048 FOR METRIC ONLY)}$$

Where

L = exact length, ft. [m]
vph = vehicles per hour (design peak hour)
cl = cycle length in seconds
PC = passenger cars, pickup and panel trucks
TK = single unit or combination tractor trailer trucks and buses
% = percent as a whole number

4-05.3 (3) (d) REQUIRED STORAGE LENGTH. The required storage length for use in design is 1.5 times the calculated exact storage for major streets and 2.0 times the calculated exact storage for freeway off-ramps. As a guide a 200 ft. [60 m] minimum storage length is desirable.

The calculated required length may be varied, when necessary, to provide a practical design consistent with capacity limiting features of the street approaches beyond the limits of the proposed improvement or with the unavoidable conflicts with other traffic movements on the same approach.

4-05.3 (3) (e) MEDIAN ACCELERATION LANES. From time to time, it may become necessary to provide a left hand acceleration lane along the median side of a four lane divided expressway downstream of a median crossover. Provision of this lane is not “typical”. In the event a project development team determines that the provision of such an acceleration lane is warranted, approval to use this concept will require a design exception in accordance with Section 2-01.9. During the consideration of the design exception request, GHQ Design will provide a copy of the exception request to GHQ Traffic for review and comment. In order to justify approval of the design exception for a median acceleration lane, the following items must be present:

- Accident history at a specific expressway intersection. Of particular concern are right angle, sideswipe, and rear end accidents that involve trucks.
- A high percentage of truck traffic originating on the minor roadway. Additionally, these trucks are of such length that they cannot be accommodated within the median opening of the expressway.
- Poor sight distance that does not provide sufficient time for a motorist in the passing lane of the expressway to avoid a slow moving truck in the passing lane downstream of the median crossover.
- Limited gaps are available in the major road traffic stream.

Additionally, the design exception should provide a median acceleration lane of such length to permit acceleration of trucks to the 85th percentile speed for vehicles operating on the expressway (See Subsection 4-06.6(10)). The acceleration lane should have a total width of 14 feet [4.2 m] with sufficient striping to denote a lane width of 12 feet [3.6 m] and a 2-foot [0.6 m] offset from the left through lane. Snowplowable Raised Pavement Markers (SRPMs) may be placed within this 2-foot [0.6 m] offset as shown in Figure 4-05.18. A shoulder, 4 feet [1.2 m] in width, should be provided on the median side of the acceleration lane. A traffic study of the intersection should be conducted by the district for at least a three-year period following construction of the median acceleration lane to document the reduction in accidents that has occurred as a result of construction of the improvement. Copies of the study are sent to the State Design and Traffic Engineers.

Approval of a median acceleration lane should not be viewed as an acceptable addition to all median crossings throughout the state. Consideration for the addition of a median acceleration lane must be obtained through the design exception process and therefore each request will be considered on a case-by-case basis.

4-05.4 TURNING RADII AND ROADWAY WIDTHS.

4-05.4 (1) TURNING RADII. Minimum design vehicle turning radii are shown in Table 4-05.3. These radii are satisfactory as minimum design where turning speeds of 10 mph [15 km/h] or less are appropriate at intersections. The radii for turning movements at urban street intersections can be less where the extra pavement width serves to increase the useable radius. When curbs are used, it is desirable to use flatter curves than those in the minimum edge of traveled way designs.

The choice of minimum design for intersection radii is given in Chapter 9 of the AASHTO Green Book. This identifies the turning radii used for the design of various roadway facilities and the type of design vehicle to use as the control. Turning paths should be checked using AutoTurn software for all allowed movements from each approach, to verify that the design vehicle can be accommodated.

The WB-67 [WB-20] should be used as the design vehicle for geometric radii for ramp terminals on the interstate and primary system, as well as for adjacent outer roads and entrances where it is anticipated this vehicle will operate. This design vehicle is the maximum semitrailer (53 ft [16.15 m] trailer length) that can legally operate in Missouri. See Figure 4-06.2 for application of the WB-67 vehicle turning requirements to ramp termini at diamond interchanges.

Turning radii for left turns for signal controlled intersections require 50 ft. [15 m] minimum to the inside edge of the turning path for efficient operation. Turning radii for channelized right turns at signal controlled intersections are 50 ft. [15 m] minimum. It is preferable to use 75 to 150 ft. [25 to 45 m] turning radii when right of way limits permit.

**TABLE 4-05.3
DESIGN VEHICLE TURNING RADII**

DESIGN VEHICLE	MINIMUM SIMPLE TURNING RADIUS ft.	MINIMUM SIMPLE TURNING RADIUS m
Passenger Car (P)	25 or 30	9.0
Truck (SU)	50 or 55	15.0
Semitrailer (WB-50) [WB-15]	75	23.0
Interstate Semitrailer (WB-67) [WB-20]	80	24.4

A simple curve with taper combinations is used for the design of channelized right turns to provide for the turning movement of semitrailer combinations. Minimum edge of traveled way designs for a simple curve with taper combinations are shown in Chapter 9 of the AASHTO Policy on *Geometric Design of Highway and Streets*, for various type vehicles and skews of intersecting roads.

4-05.4 (2) ROADWAY WIDTHS. Traveled way widths of turning roadways are controlled by the volumes of turning traffic and the types of vehicles to be accommodated. Where lane widths of channelized right turn lanes exceed 20 ft. [6.0 m] in width, lane delineation with painted lane markings are appropriate to restrict the turning movement operation to one lane use. Vehicles with wider offtracking wheel paths can still use the extra paved width to negotiate the turn. Required roadway widths for the vehicle offtracking can be determined by templates furnished from General Headquarters Design and Chapter 3 of the AASHTO Policy on *Geometric Design of Highway and Streets*. An additional 1 ft. [0.3 m] clearance outside the maximum wheel offtracking along each side is provided for the turning roadway width.

4-05.4 (2) (a) LANE WIDTHS. At signal controlled intersections where existing street widths determine the lane use for various traffic movements, lane widths 10 to 13 ft. [3.0 to 3.9 m] are used, with widths of 11 to 13 ft. [3.3 to 3.9 m] desirable for safety and efficiency of operation.

4-05.4 (2) (b) INTERCHANGE OFF RAMPS. Off-ramps into signalized intersections are a minimum of 24 ft. [7.2 m] in width at the intersection when construction peak hour volumes are 60 vph or greater, or the design peak hour volume is from 90 to 120 vph or greater, in order to separately channel, store, and control right and left turning movements. The total length of 24 ft. [7.2 m] traveled way width is determined by the storage length required for the heavier of the two movements.

4-05.5 SIGHT DISTANCE. The minimum sight distance at all grade intersections, entrances, and median openings, measured along the centerline of the main road, is equal to twice the stopping sight distance based on the design speed of the main road. This distance is based on a 3.5 ft. [1070 mm] height of eye and 0.5 ft. [150 mm] height of object, if at all practicable. In special cases, where this is not practicable, the distance is based on a 3.5 ft. [1070 mm] height of eye and 4.25 ft. [1300 mm] height of object. The minimum sight distance at all grade intersections measured along the minor road, is the stopping sight distance based on the design speed of the minor road. Exceptions are sometimes necessary where the minor road is being improved to intersect a more important road. Where the more important road is being improved, the minor road is located or improved as required to obtain the required sight distance. If the design speed of the minor road is not known, a design speed of 30 mph [50 km/h] is used. Grades are planned and access points are located as required to provide the required sight distance. Minimum sight distance requirements are tabulated in Table 4-05.4. The values tabulated are exceeded where practicable. These sight distance requirements insure that intersections and access points are visible to approaching traffic.

TABLE 4-05.4
MINIMUM SIGHT DISTANCE AT INTERSECTIONS

DESIGN SPEED (mph)	ALONG MAIN ROAD 3.5' x 0.5' 2 x S.S.D. (ft.)	ALONG MINOR ROAD 3.5' x 0.5' S.S.D. (ft.)	"d" (ft.)
30.00	400.00	200.00	160.00
35.00	450-500	225-250	160.00
40.00	550-650	275-325	185.00
45.00	650-800	325-400	200.00
50.00	800-950	400-475	220.00
60.00	1050-1300	525-650	260.00
70.00	1250-1700	625-850	310.00

	ALONG MAIN ROAD 1070 mm - 150 mm 2 x S.S.D. (m)	ALONG MINOR ROAD 1070 mm - 150 mm S.S.D. (m)	"d" (m)
50.00	120 - 140	60 - 70	40.00
60.00	160 - 180	80 - 90	50.00
70.00	200 - 240	100 - 120	60.00
80.00	240 - 280	120 - 140	65.00
90.00	280 - 340	140 - 170	75.00
100.00	320 - 420	160 - 210	85.00
110.00	360 - 500	180 - 250	90.00
120.00	420 - 580	210 - 290	100.00

A triangle of right of way is acquired for required sight distance and visibility at all state route and local road intersections, except where the normal right of way will provide the equivalent of the triangle of right of way. The triangle is graded to the elevation of shoulder point to shoulder point of intersecting roads, to provide the sight distance when the intersection is in a cut. The backslope is graded to the normal cut slope used on the project for the main roadway. Controlled access right of way at intersections for otherwise normal access routes is provided at all state routes and all side roads which intersect a state route carrying over 1700 design ADT. See Section 4-02 for further details.

The dimensions for the additional triangle of right of way, where required, are determined by connecting points on the centerline of the intersected roads a distance "d" from the point of intersection, as tabulated in Table 4-05.4. Where grading is required to provide sight distance, additional right of way may be required to provide room for the grading. The design speed of each intersecting road is used to determine "d" in Table 4-05.4. For side road approaches where the design speed is unknown, an assumed design speed of 30 mph [50 km/h] is used. The right of way is dimensioned in 5 ft. [1.0 m] increments by scaling.

4-05.6 SKEWS. The skew of at-grade intersections and entrances is held at or below 20 degrees, if practical.

4-05.7 CROSSROAD DESIGN CRITERIA. Crossroads are sometimes reconstructed some distance beyond normal intersection limits because of design controls or for the construction of grade separations or interchanges. In such cases, the reconstruction is planned to meet basic design criteria based on the functional classification and design traffic on the crossroad whether the crossroad is a state route or not. On crossroads not part of the state highway system it is the policy to maintain roads being improved with a state highway project to within the limits of the "normal" right of way. Normal right of way includes sight distance right of way purchased at public road approaches.

4-05.8 ROUNDABOUTS

4-05.8 (1) INTRODUCTION AND DEFINITIONS. A roundabout is defined as a circular traffic intersection featuring yield control on all entering legs, one-way continuous flow within the circulatory roadway, channelization of approaches, and appropriate geometric curvature to keep circulating speeds low. Roundabouts may contain as few as three legs, and roundabouts with more than four legs are not uncommon. Figure 4-05.6 illustrates a typical roundabout and identifies key geometric elements.

Subsection 4-05.8 applies to single-lane roundabouts; Subsection 4-05.9 applies to multi-lane roundabouts.

These guidelines do not present a comprehensive procedure for roundabout design, but are intended to provide guidance related to key design parameters. Other publications, such as FHWA's *Roundabouts: an Informational Guide*, may be referred to as needed. Where direct guidance on design elements is not given, standard MoDOT intersection design practices will govern.

It should be noted that certain roundabout characteristics can vary depending on the nature of the roundabout's location, whether urban or rural. Where these variations are noteworthy, they are described in the appropriate section.

4-05.8 (2) JUSTIFICATION PROCEDURES. The process of selecting a roundabout as the preferred form of traffic control for a given intersection will have three stages. If a roundabout fails at any of these stages, it should not be considered.

Stage 1: Appropriateness. The initial stage involves a "broad brush" determination of whether the site is appropriate for a roundabout. Figure 4-05.7 lists potentially appropriate and inappropriate sites for roundabouts. The site conditions should be compared to these lists to determine whether a roundabout merits further consideration.

Stage 2: Operational Feasibility. Once a roundabout is determined to be a potentially appropriate form of traffic control, the second stage involves testing to determine whether a roundabout could function at acceptable levels of service. A capacity analysis is performed to determine volume-to-capacity (v/c) ratio and basic lane needs. The analysis should use the procedures outlined in Subsection 4-05.8 (3), based on peak-hour volumes appropriate for local conditions. The analysis should be conducted for both Construction Year and Design Year.

Stage 3: Comparative Performance. Once it is determined that a roundabout could function acceptably, the final stage is to compare its performance to that of other potential forms of control (such as signalization). The comparison may include, but should not necessarily be limited to: operational performance, construction cost, life-cycle cost, right-of-way considerations, “reserve capacity” (the ability to accommodate traffic growth), and constructability.

The justification procedure for each roundabout should be documented in a memorandum describing the procedures and results of each of the three stages, and summarizing the reasons for selecting roundabout control. The memorandum should be part of the conceptual report for the project.

4-05.8 (3) OPERATIONAL/CAPACITY ANALYSIS. The capacity model described in the *Highway Capacity Manual* (HCM) should be used as the primary check of a roundabout’s capacity. The HCM model applies only to single-lane roundabouts. The model is fundamentally based on gap-acceptance theory. Capacity values are developed for each approach based on peak-hour circulating volumes. Roundabouts should be designed to operate at no more than 85 percent of capacity; this concept is referred to as “practical capacity.”

Additional analysis should be performed to refine the geometric design and provide more information for Stage 1 and 2 of the justification procedure described in Subsection 4-05.8 (2). Operational analysis should use the SIDRA software package. If simulation is desired, the VISSIM software package should be used.

4-05.8 (4) FUNDAMENTAL DESIGN PRINCIPLES. The three fundamental considerations in roundabout design are design speed, capacity, and design vehicle. These three parameters result in a series of tradeoffs – because while large-diameter roundabouts may provide higher capacity and better truck accommodation, they tend to reduce safety through higher design speeds. Subsection 4-05.8 (5) discusses design speed; Subsection 4-05.8 (3) discusses capacity principles; and Subsection 4-05.8 (6) discusses accommodation of the design vehicle. Figure 4-05.8 illustrates minimum dimensions for a standard four-leg roundabout that meets the fundamental design criteria.

4-05.8 (5) DESIGN SPEEDS. A maximum design speed of 25 mph (40 km/h) should be used. A typical range of 18 to 22 mph (29 to 35 km/h) is desirable. Speed control at roundabouts is primarily achieved through deflection of entering vehicles. Design speeds should be calculated on a move-by-move basis, by drawing the fastest path allowed by the roundabout geometry. Figure 4-05.9 illustrates how these speeds are measured. The designer should develop a speed matrix, like the one shown in Figure 4-05.9, to illustrate that all speeds have been checked and that design speeds do not exceed the maximum.

4-05.8 (6) DESIGN VEHICLE. The design of all roundabouts on the state highway system should accommodate a WB-67 design vehicle. In order to keep design speeds below the allowable maximum (see Subsection 4-05.8 (5)), a truck apron may be provided (see Subsection 4--05.8(9)).

Emergency vehicles can generally be accommodated at roundabouts that have been designed for WB-67 design vehicles. Turning paths should be checked using AutoTurn software for all allowed movements from each approach, to verify that the design and emergency vehicles can be accommodated.

Transit stops should not be placed within roundabouts. Transit stops located near roundabouts should include bus turnouts in order to promote traffic flow and increase safety.

4-05.8 (7) SIGHT DISTANCE. Two categories of sight distance are examined at roundabouts: stopping sight distance and intersection sight distance.

Three types of stopping sight distance are checked, at a minimum: Approach, Circulatory and Exit/Pedestrian. Figure 4-05.10 illustrates the methods used to measure these values. The sight distances are based on a driver eye height of 3.5 feet [1070 mm] and an object height of 2.0 feet [0.6 m].

Two types of intersection sight distance are measured: Adjacent Entry and Circulatory. Figure 4-05.10 illustrates the methods used to measure these values. The sight distances are based on a driver eye height of 3.5 feet (1070 mm) and an object height of 3.5 feet (1070 mm).

4-05.8 (8) CENTRAL ISLAND. The non-truck-apron portion of the central island should be curbed with a six-inch (150 mm) barrier curb. The central island should be circular in shape. In certain situations, non-circular shapes such as ovals or ellipses may be used. Such shapes may be justified by irregular approach geometry or an odd number of legs. In all cases, the design of the island is governed by the roundabout's design speed (see Subsection 4-05.8 (5)) and the design vehicle (see Subsection 4-05.8 (6)).

For landscaping considerations on the central island, see Subsection 4-05.8 (16).

4-05.8 (9) TRUCK APRON. A truck apron (See Figure 4-05.6) is a raised mountable portion of the central island that provides additional circulatory width for large vehicles. A truck apron may be provided when the central island geometry, as designed to maintain low circulatory speeds, would prevent the unimpeded circulation of the design vehicle.

The outside edge of the apron should be curbed with a three-inch mountable curb. The width of the truck apron should be the minimum necessary to accommodate the design vehicle (see Subsection 4-05.8 (6)). An overly wide apron can confuse drivers by creating a distorted sense of proportion. A typical maximum apron width is 10 feet (3.0 m).

The truck apron will be concrete and will provide a visual contrast with the circulating roadway.

4-05.8 (10) CIRCULATORY ROADWAY. The width of the circulatory roadway should be the minimum necessary to accommodate the design vehicle (see Subsection 4-05.8 (6)). It is equal to the difference between the inscribed circle radius and the central island/truck apron radius. Parking or stopping in the circulatory roadway is prohibited.

The outer edge of the circulatory roadway should be curbed (except at openings for entry and exit legs). For cross-slope and drainage considerations on the circulatory roadway, see Subsections 4-05.8 (13) and 4-05.8 (16), respectively. For pavement marking considerations on the circulatory roadway, see Subsection 4-05.8 (15).

4-05.8 (11) SPLITTER ISLANDS. Splitter islands serve two primary functions at a roundabout: physical separation of entering and exiting traffic (consequently reinforcing one-way circulation), and deflection of entering traffic (to control entering speeds). In addition, a splitter island can serve as a pedestrian refuge. Splitter islands will be curbed with barrier curb.

The splitter island geometry is typically asymmetrical – generally, the entry side provides deflection to slow speeds, while the exit side provides a larger opening to facilitate egress.

The minimum width of a splitter island without a pedestrian crossing is 2 feet (0.6 m); with a pedestrian crossing, the minimum width (at the crossing) is 6 feet (1.8 m). The pedestrian opening (see Figure 4-05.6) will be a minimum of 10 feet (3.0 m) wide. See Subsection 4-05.8 (14) for additional guidance on pedestrian treatments.

On approaches with a wide median or two-way left-turn lane (TWLTL), a narrowing of the existing median, to match the splitter island dimensions discussed above, will generally be needed in order to achieve necessary entry deflection.

4-05.8 (12) APPROACH LEGS. Approach legs should be curbed with barrier curb (on the right side) for at least half the length of the splitter island. A typical minimum entry width is 16 feet (4.8 m) (curbface-to-curbface) to allow bypassing of a stalled vehicle. Exit widths will be controlled by the turning path of the design vehicle (see Subsection 4-05.8 (6)). A typical minimum exit width is 18 feet (5.4 m).

Right-turn "bypass lanes", physically channelized so that right-turning vehicles do not enter the roundabout, may be considered on approach legs (see Figure 4-05.6). Bypass lanes should be avoided where moderate to high pedestrian or bicycle volumes are anticipated. Pedestrian crossings are discouraged across bypass lanes. Following are potential applications for which bypass lanes might be considered (this list is not exhaustive):

- To reduce the amount of vehicles entering the roundabout
  - If right turns compose more than half of the entry volume, or
  - If the right-turn volume exceeds 300 vehicles during a single hour

- To resolve geometric difficulties
  - An approach with two existing lanes intersecting a roundabout at which only one circulating lane is needed
  - An acute angle between adjacent legs

Bypass lane recommendations and designs should account for potential weaving and merging issues. The presence of closely spaced intersections, nearby driveways, and "entrapment" lanes can negatively affect bypass lane operations. These issues should be thoroughly examined before recommending a bypass lane.

Dropping a lane approaching a roundabout should not typically occur within a distance under 200 feet [60 m], measured from the downstream end of the lane drop taper.

Ideally, the angles between all adjacent roundabout legs are equal (for example, 90° on a 4-leg roundabout). Maximizing the spacing between legs promotes smooth traffic flow. The designer should attempt to space the approaches such that the distance between the extended centerlines of the entry lanes of any two adjacent approaches, measured along the centerline of the circulatory roadway, is a minimum of 50 feet (15 m) (see Figure 4-05.11). If reasonable spacing cannot be achieved, careful design consideration is needed to optimize operational characteristics.

4-05.8 (13) GRADES, CROSS-SLOPES, SUPERELEVATION. Figure 4-05.11 shows a typical roundabout cross-section.

Ideally, roundabouts should be constructed at level intersections. The maximum approach grade should be limited to 3 percent.

The circulatory roadway should be designed with -2 percent superelevation (away from the central island). The slope of the truck apron should be -4 percent (away from the central island).

4-05.8 (14) BICYCLISTS AND PEDESTRIANS. No explicit bicycle facilities or markings are provided within the circulating roadway or central island. If bike lanes are provided on the intersecting roadways, they should be transitioned to off-street facilities sufficiently in advance to avoid introducing new driver decision points in the vicinity of the roundabout. Bicyclists may choose to enter the roundabout as a vehicle (using the circulatory roadway) or, if multi-use facilities are provided, bicyclists may use them. Figure 4-05.12 illustrates potential bicycle-lane treatments, including bicycle ramps and bicycle platforms.

The design of a roundabout should not encourage pedestrian movement within the circulatory roadway or central island. If crosswalks are determined to be necessary, they should typically be located approximately one vehicle length behind the yield line (to allow a pedestrian to cross behind a stopped vehicle), unless it is determined that a larger distance is needed to prevent exit queues from backing into the circulatory roadway. Even if no sidewalks are provided, curb cuts and splitter island openings should still be provided at the standard locations in anticipation of future crosswalks. See Subsection 4-05.8 (15) for details on crosswalk markings, and Subsection 4-05.8 (11) for details on pedestrian accommodations at the splitter islands. In all cases, pedestrian-related design should conform to the requirements of the Americans with Disabilities Act (ADA).

4-05.8 (15) SIGNING AND PAVEMENT MARKING. Figure 4-05.13 illustrates typical signing and pavement marking for a roundabout on the state highway system.

4-05.8 (15)(a) ROUNDABOUT SIGNING GUIDELINES.

Regulatory: YIELD (R1-2) signs are posted on the right and left side of each approach. ONE WAY (R6-1R) signs, with chevron plates (W1-8), are posted on the central island facing each approach. Pictorial KEEP RIGHT (R4-7) signs should be used on splitter island approach noses.

Warning: Pictorial ROUNDABOUT AHEAD ("chasing arrow") signs, with advisory "ROUNDABOUT" plates and advisory speed plates (W13-1), are placed in advance of the roundabout on all approaches. The posted advisory speeds should reflect the circulatory speed of the roundabout. (Advisory speeds are posted in multiples of 5 mph.) Pedestrian crossing (W11-2) signs, with directional arrow plates (W16-7P), may also be used at the crosswalk locations. Pictorial YIELD AHEAD (W3-2a) signs may also be used on each approach. These last two signs may be particularly applicable in rural, high-speed settings, to increase the level of warning conveyed the approaching driver.

Guide: Advance diagrammatic should be considered for roundabouts with more or fewer than four legs, and in other unusual geometric situations. Diagrammatic signs are mandatory on freeway interchange off-ramps. Exit guide signs (D1-1) may also be used to designate the destinations of each exit from the roundabout.

4-05.8 (15)(b) ROUNDABOUT PAVEMENT MARKING GUIDELINES.

Circulatory roadway: The left edge of the circulatory roadway (adjacent to the central island) is marked with a 4-inch (100 mm) solid yellow stripe. The right edge is marked with a 4-inch (100 mm) solid white stripe.

Approach legs: The yield line will be dashed white (see Figure 4-05.10). A painted white YIELD legend may be used. A 4-inch (100 mm) solid white stripe is used along the right edge of the approach; a 4-inch (100 mm) yellow stripe is used along the left edge, tying into the existing double-yellow centerline in advance of the splitter island approach nose. Solid yellow diagonal 24-inch (600 mm) hatched lines, separated by 20 feet, should also be provided in advance of the splitter islands.

Pedestrian crossings: Crossings should be marked with white mid-block (zebra) markings (see Standard Plan 620.00). Crossings are located as specified in Subsection 4-05.8 (14). Alternative crossing treatments, such as colored or textured pavement, should be approved by the District Engineer. In all cases, pedestrian-related design should conform to the requirements of the Americans with Disabilities Act (ADA).

4-05.8 (16) LANDSCAPING, LIGHTING AND DRAINAGE. Any landscaping should be located so as not to obstruct sight distance (see Subsection 4-05.8 (7)). However, it is generally a good idea to locate landscaping in the center of the central island to create a visible, vertical obstruction that can be seen well in advance. This has the added effect of blocking views between opposing approaches. Landscaping should not attract pedestrians to the center of the roundabout – in fact, low landscaping can be used on the outside of the roundabout (between the sidewalk and the curb) to provide a physical barrier to direct pedestrians toward the crosswalks. The splitter islands should not be landscaped. Landscaping should not introduce any hazards to the intersection.

Landscaping should be designed for minimal maintenance. If vegetation within the roundabout requires watering, a sprinkler system should be installed.

Lighting levels at roundabouts should generally conform to MoDOT guidelines for lighting levels at intersections. Key locations that should be well-lit include the splitter island approach noses, all conflict areas where traffic enters the roundabout, and all places where vehicles exit the roundabout. The roundabout should be lit from the outside towards the center. Figure 8-01.4 illustrates a typical lighting layout at a roundabout. If a 30-foot (9.0 m) luminaire height is used, 8 luminaires are recommended. If a 45-foot (13.5 m) height is used, 4 luminaires are recommended.

Drainage for the roundabout and approach legs should follow standard MoDOT design criteria. Additional consideration should be given to the drainage of the central island.

4-05.8 (17) TRAFFIC CONTROL DURING CONSTRUCTION. The designer must consider the implications of the roundabout construction period on local traffic flow. An initial constructability check, including staging and interim traffic control concepts, is necessary. In accordance with standard MoDOT policy, the designer should attempt to minimize detours during construction, while maximizing safety and minimizing motorist confusion. Nighttime and off-peak construction activities are encouraged. If the roundabout location is to be "bypassed" during construction, design speeds for the temporary bypass should be similar to those of the completed roundabout, so as not to result in a perceived loss of level of service.

4-05.9 MULTI-LANE ROUNDABOUTS. MoDOT defines a multi-lane roundabout as a roundabout with more than one lane on any portion of the circulatory roadway. Unless otherwise specified herein, the guidelines for single-lane roundabouts (Subsections 4-05.8(1) through 4-05.8(17)) also apply to multi-lane roundabouts.

One of the most important considerations in multi-lane roundabout design is driver understanding. Every facet of the design should be oriented toward conveying the safe and proper method of driving the roundabout. At a typical two-lane roundabout, the driving rules are: (1) if you plan to exit less than halfway around, enter the roundabout using the outside lane; (2) if you plan to exit more than halfway around, enter the roundabout using the inside lane; (3) if you plan to exit halfway around, you can enter using either lane. Figure 4-05.14 illustrates these permitted maneuvers at a typical two-lane roundabout. In certain cases (some of which are described in Subsection 4-05.9(2)), deviations from these rules may be necessary. In all cases, expectations should be clearly conveyed to drivers.

In planning roundabouts, it is advisable to consider the differences between short- and long-term needs. If a single-lane roundabout will suffice in the near-term, but a multi-lane roundabout will be needed in the future, the designer should consider constructing a single-lane roundabout with accommodations for relatively simple conversion to a multi-lane configuration in the future. Examples of such accommodations might include wider splitter islands or a larger initial central island diameter. Particular attention should be paid to the amount of construction necessary to convert from a one-lane to two-lane configuration, and to the traffic control that would be necessary during such construction. As stressed throughout Subsection 4-05.8, the minimization of design speeds should continue to be a key design objective.

In all cases, thorough conceptual planning should be completed before design begins. This includes detailed analysis, geometric feasibility assessments, and consideration of user characteristics.

4-05.9 (1) JUSTIFICATION PROCEDURES. In general, the justification procedures outlined in Subsection 4-05.8(2) apply to multi-lane roundabouts. Only the volume-related justifications change: multi-lane roundabouts may be considered appropriate for intersections with design-year entering peak-hour volumes typically not exceeding 3,700 vehicles. (Certain treatments, such as bypass lanes, could allow the accommodation of higher volumes.)

For multi-lane roundabouts, the justification process should also consider the nature of motorists in the area of the proposed roundabout (e.g. tourists, trucks, buses, senior drivers, etc.).

4-05.9 (2) PARTIAL MULTI-LANE CONFIGURATIONS. Multi-lane roundabouts present more complex design issues than those of single-lane roundabouts. They also present a more complex set of decisions to drivers. In recognition of these facts, roundabouts should be designed to minimize the number of circulating lanes to the extent that is operationally feasible. In other words, single-lane circulating roadways are preferred over multi-lane. The most significant point of confusion at a multi-lane roundabout is at the exit, where it may not be clear to motorists who may continue circulating and who may not. Single-lane exits can potentially reduce this confusion.

With the above concept in mind, it will often be desirable to consider roundabouts on which only a portion of the circulatory roadway carries multiple lanes. Such roundabouts can be subdivided into two categories: (1) instances where an additional "turning" lane is added within the roundabout to facilitate a heavy movement, and (2) instances when additional "through" capacity is carried through the roundabout on one street but not another (sometimes referred to as a "2-lane/1-lane" configuration). Figure 4-05.15 illustrates examples from both these categories of partial multi-lane roundabouts.

At freeway interchanges with one-way ramps (such as diamond interchanges), the teardrop configuration, which prevents circulating movement in front of one approach, may be used (see Figure 4-05.15). Although one approach will not be required to yield to circulating traffic, that approach should still be designed to slow entering traffic to the required speeds discussed in Subsection 4-05.9(8). The designer should verify that the elimination of U-turn movements on the teardrop leg would not result in access problems on nearby roadways.

4-05.9 (3) **TYPICAL DIMENSIONS.** Roundabout dimensions are a function of design speed and design vehicle: the roundabout should be large enough to accommodate the design vehicle (see Subsection 4-05.9(9)), but not so large as to encourage excessive speeds (see Subsection 4-05.9(8)). These two parameters should be the guiding elements in choosing roundabout dimensions – however, the following dimensions can be used as a general guide: In urban settings, the inscribed circle diameter (see Figure 4-05.6) for a four-leg two-lane roundabout typically ranges from 150 to 180 feet [45 to 55 meters]. In rural settings, the inscribed diameter typically ranges from 180 to 200 feet [180 to 200 feet].

4-05.9 (4) **FIVE OR MORE LEGS.** Multi-lane roundabouts with more than four legs are extremely complex from a driver's point of view. They present unique challenges in signing (see Subsection 4-05.9(13)) and pavement marking (see Subsection 4-05.9(14)). Wherever possible, the use of partial multi-lane configurations is encouraged with roundabouts having five or more legs. (See Subsection 4-05.9(2).)

4-05.9 (5) **THREE-LANE ROUNDABOUTS.** Roundabouts with more than two circulating lanes are discouraged on Missouri state highways, and will be considered a design exception.

4-05.9 (6) **CAPACITY CONSIDERATIONS.** Many of the operational and capacity considerations of Subsection 4-05.8(3) apply to multi-lane roundabouts. However, the Highway Capacity Manual (HCM) does not currently address multi-lane roundabouts, so the SIDRA and VISSIM software packages (discussed in Subsection 4-05.8 (3)) should be the primary analysis tools. The "practical capacity" used in designing each approach to a multi-lane roundabout should be 75 percent of the estimated approach capacity. The designer should ensure that the lane-usage assumptions of the analysis are consistent with the proposed operation of the roundabout.

4-05.9 (7) **SIGNALIZATION.** Traffic signals will not be allowed within, or at any exit/entry point on, roundabouts on the Missouri state highway system.

MoDOT does not specify a standard spacing distance between roundabouts and adjacent signalized intersections. Instead, the designer should ensure, through operational analysis, that adequate distance is available to accommodate 95^{th}-percentile queue lengths between a roundabout and an adjacent intersection. This includes queues approaching the roundabout as well as queues approaching the adjacent intersection.

4-05.9 (8) **DESIGN SPEEDS.** A maximum design speed of 30 mph (50 km/h) should be used for multi-lane roundabouts. A typical range of 23 to 27 mph (37 to 43 km/h) is desirable. Design speeds will be calculated as specified in Subsection 4-05.8(5).

4-05.9 (9) **DESIGN VEHICLE.** Design vehicle requirements listed in Subsection 4-05.8(6) apply to multi-lane roundabouts, with one addition. The designer should consider the circulating paths of large vehicles entering the roundabout. At smaller two-lane roundabouts, operators of large vehicles may find it necessary to straddle both circulating lanes. At larger roundabouts, large vehicles may be able to maintain a constant lane. The choice between these two options will affect how turning templates are checked per Subsection 4-05.8(6).

For roundabouts at which trucks are likely to straddle the circulating lanes, a truck apron is typically not necessary. At roundabouts designed to accommodate two circulating trucks side-by-side, a truck apron may be necessary to keep the circulatory roadway width to a minimum.

4-05.9 (10) **APPROACH GEOMETRY.** The design of multi-lane roundabout entries should attempt to avoid "vehicle path overlap" wherever possible, as described below.

On entry, vehicle path overlap occurs most commonly when an entering motorist in the outside lane finds it natural to "drift" toward the inside lane when entering the roundabout, as illustrated in Figure 4-05.16. One potential method to discourage vehicle path overlap on entry is to design the entry flare so that a tangent can be drawn between the entry lane line and the circulating lane line, as illustrated in Figure 4-05.16.

Although eliminating vehicle path overlap is an important goal, the designer should simultaneously take care to avoid promoting excessive entry speeds. In cases where path overlap and design speed conflict, minimization of design speeds should receive higher priority.

At larger roundabouts, the solutions described above may result in either an excessively sharp entry flare or an excessively wide splitter island - so it may be difficult to avoid vehicle path overlap.

4-05.9 (11) RIGHT-TURN TREATMENTS. As discussed in Subsection 4-05.8(12), bypass lanes are a potential method for addressing heavy right-turn movements. A less preferred (due to lower capacity) but acceptable method is to include a dedicated right-turn lane that is not physically separated from the roundabout. If this method is used, the circulatory roadway in that quadrant of the roundabout should be widened to allow the right-turning vehicles to enter the roundabout simultaneously with adjacent through vehicles on the same approach. This configuration is potentially more confusing than a typical bypass lane configuration, and should only be used where necessitated by right-of-way or other physical constraints. Adequate signing and marking should accompany this configuration.

4-05.9 (12) EXIT GEOMETRY. At two-lane roundabout exits, attention should be paid to lane width and exit radius in order to discourage vehicle path overlap. Vehicle path overlap can occur if the exit radius is so small that motorists in the inside lane will tend to "drift" into the outside lane when exiting. A potential method to check for exit overlap, illustrated in Figure 4-05.16, is to draw (on a scaled plan) the smoothest continuous connection between the centerline of the circulatory roadway and the centerline of the exiting lanes. If the radius of this connection is less than the radius of the centerline of the circulatory roadway (implying a lower design speed), vehicle path overlap may result. The exit radius and width may need to be adjusted. As with entry path overlap, the exit geometry design is a tradeoff between keeping speeds low enough to maximize pedestrian safety and keeping radii large enough to avoid vehicle path overlap. In cases where path overlap and design speed conflict, minimization of design speeds should receive higher priority.

To minimize motorist confusion, single-lane exits should be considered wherever operationally feasible. (Some examples are shown in Figure 4-05.15.)

Typically, it is not desirable to require motorists to merge immediately after exiting a two-lane roundabout (via a lane drop). However, in some cases, having two departure lanes may be desirable for roundabout processing capacity, while the basic underlying roadway may only carry one lane per direction. If a lane drop (reduction) is necessary, it should occur a minimum of 200 feet [60 m] from the roundabout exit, with a standard merge taper.

4-05.9 (13) SIGNING. All the provisions of Subsection 4-05.8(15)(a) apply to multi-lane roundabouts, but additional signing is necessary to convey lane usage. Figure 4-05.17 illustrates the preferred method, which uses overhead signage to delineate lane usage. However, each site should be evaluated on its own merits to determine signage needs. In general, the signing for a proposed roundabout should be thoroughly considered at the concept stage, because the effectiveness of a roundabout – even one with excellent geometric design – can be compromised if drivers do not understand how to drive it.

4-05.9 (14) PAVEMENT MARKING. All the provisions of Subsection 4-05.8(15)(b) apply to multi-lane roundabouts, but additional markings are needed to help delineate the circulatory lanes. Figure 4-05.17 illustrates typical pavement marking for a multi-lane roundabout; specific elements are discussed below. Standard Plan 620.00 illustrates standard pavement arrows and placement.

The function of circulatory lane striping is to reinforce permitted movements circulating and exiting the roundabout. For a standard two-lane roundabout, a solid 4-inch [100 mm] white line will divide the circulating lanes as they pass a splitter island. In cases of odd geometry or more than four legs, customized modifications to the typical striping pattern may be necessary.

Pavement arrows within the circulatory roadway should typically not be used.

Where multiple lanes enter a roundabout, a solid 4-inch [100 mm] white line will separate the lanes on the approaches. If this line is a continuation of an existing intermittent lane-striping pattern, the conversion to the solid line should occur a minimum of 100 feet [30 m] in advance of the yield line. Similarly, multiple lanes exiting a roundabout will be separated by a solid 4-inch [100 mm] white line, which should remain solid for a minimum of 100 feet [30 m] beyond the roundabout exit.

At conventional multi-lane roundabouts with three or four legs, lane-use arrow markings (supplemented by appropriate signage) may be used on the approaches. If arrows are used, one set of arrows should be located near the yield line, and another set should be located in advance.

4-05.9 (15) PEDESTRIAN ISSUES. All of the pedestrian considerations described in Subsection 4-05.8(14) apply to multi-lane roundabouts. However, due to wider approaches and exits, multi-lane roundabouts result in more pedestrian exposure than do single-lane roundabouts. Special care should be taken to maximize pedestrian safety at multi-lane roundabouts. This could include special treatments such as decorative crosswalks, raised crosswalks (which have the added effect of reducing vehicle speeds), or alternative crosswalk locations (further away from the roundabout) that maximize pedestrian visibility and comfort.

4-05.9 (16) DRAINAGE, SUPERELEVATION. In general, the provisions of Subsection 4-05.8(13) apply to multi-lane roundabouts, but in certain instances, it may be advisable to crown the circulating roadway. One advantage of this approach is that it can promote consistency in speeds by superelevating the tighter-radius inner lane and negatively superelevating the higher-radius outer lane. The drainage design would become more complex, as inlets and/or slotted drains would be needed on both the inside and outside edges of the circulatory roadway.

4-05.9 (17) LIGHTING. See Subsection 4-05.8(16) for guidelines on lighting roundabouts. The key lighting locations discussed in that Subsection also apply to multi-lane roundabouts: the splitter island approach noses, all conflict areas where traffic enters the roundabout, and all places where vehicles exit the roundabout. At larger roundabouts, the general lighting layout guidelines of Figure 8-01.4 may be inadequate – the designer should check lighting levels to verify adequacy.

4-05.9 (18) PUBLIC EDUCATION. Because of the complexity presented to drivers by multi-lane roundabouts, some form of public education program should be considered with each installation – especially when multi-lane roundabouts are new to a given area. Safety is increased when motorists are aware of the proper method of driving a multi-lane roundabout.

4-05.10 PLANS. The plans show complete details for all intersections, approaches, and median openings not detailed on standard plans. The plans include quantities for grading, drainage, and surfacing. The plans also show the station at right angles from the main roadway or outer roadway to the intersection of the right of way line with the centerline of all driveways as illustrated in Section 4-10. In most instances, unless critical, this station need not be computed but may be scaled. The driveway width shown on the plans will be a width appropriate for the type of development to be served and the associated traffic needs.